DISCOVERY

Delineation of subsurface lithology and aquifers in Kajola Town, Ondo State using geoelectrical resistivity techniques

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ABSTRACT

Assessment of groundwater yielding region using geophysical investigation was carried out to identify possible potential aquifer using Vertical Electrical Sounding (VES) method and 2-Dimensional method in Kajola town, Ondo State. The Schlumberger array configuration was used for acquiring data for VES and Wenner array for 2-D methods. Seven (7) Vertical Electrical Soundings and Ten (10) 2-D images were obtained. VES data acquired from the study area were processed using iteration software WINRESIST. Also, the 2-D data acquired were analysed, processed and inverted using a software called RES2DINV to obtain the 2-D resistivity structure. Varying anomalous features along each profile were delineated from the distribution of areas of high, low and moderate resistivity. The model also exhibits gradational change in resistivity with depth, and with varying subsurface topographies. VES results clearly indicate that the depth of the aquifers are 8.9m, 12.5m, 16.5m, 22.7m, 16.5m, 7.8m and 8.0m for VES 1, VES 2, VES 3, VES 4, VES 5, VES 6 and VES 7 locations respectively. Thus, the average depth to aquifer is at the depth range between 13m and 20m. The geologic layer of this aquifer zone is characterized by structural features like fractures and pore spaces that enhance groundwater permeability and storage.

Keywords: Lithology, Aquifer, Delineation, Vertical Electrical Sounding (VES), 2D Imaging Technique

1. INTRODUCTION

Water is essential to mankind in various ways, for some communities that they depend on for domestic, agricultural, and industrial uses. It is an element of the landscape demanding rigorous scientific quantification and analysis (Brown and Parizek, 1971). In recent times, the electrical resistivity method has been developed speedily. The One-dimensional (1-D) resistivity technique was used in the pioneer works of Conrad Schlumberger, where Vertical Electrical Sounding (VES) was the most used in this technique using Schlumberger array (Koefoed,

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1979; Kunetz, 1966). The major development of electrical resistivity method in the last 20 years is the Two dimensional (2-D) and Three dimensional (3-D) imaging techniques using common electrode arrays configuration such as Wenner, Schlumberger, Pole-Pole, Pole-Dipole, Dipole-Dipole, Gradient array and square arrays (Bentley and Gharibi, 2004; Dahlin and Bernstone, 1997; Dahlin et al., 2002; Dutta et al., 2006; Griffiths and Barker, 1993; Gunther et al., 2006; Loke, 2012; Loke and Barker, 1996a; Loke and Barker, 1996b). Many works used the VES and/or 2D techniques to delineate groundwater aquifers such as (AL-Shemmari, 2012; Amin, 2008; Dahlin and Zhou, 2004; Hago, 2000; Kumar et al., 2010; Medeiros and Lima, 1990; Moscow, 2001; Nwankwo, 2011; Olugbenqa, 2009; Ratnakumari et al., 2012; Vander-Velper, 1988; Van Overmeeren, 1989). Other literatures such as (AL-Zubedi and Thabi, 2012; Ayolabi et al., 2009). Also, AL-Zubedi and Thabit, (2012) found that the 2-D imaging is the best in delineating shallow aquifers. The aim of this study is to assess the groundwater yielding region and to identify possible potential aquifer using (VES) and 2-Dimensional methods in Kajola town, Ondo State. This is to delineate groundwater aquifers in complex sedimentary deposits using VES and 2-D imaging techniques and to compare them to showing the best in determining the aquifers especially at depths of more than 100 m. So, it will take the use of the long survey lines for VES and 2-D techniques to delineate the deep aquifers in complex sedimentary areas.

Study Area

The study area is located within the Kajola town in Ondo State, Nigeria. It lies between Latitude 7°10'25" North and Longitude 5°0'4" East. It is bounded in the North by Ile Oluji/Okeigbo Local Government Area (LGA), East by Idanre L.G.A, South by Odigbo L.G.A, and West by Ondo West L.G.A, all in Ondo State (Figure 1). Geologically, Kajola is a true Niger Delta with a typical feature of massive top sand soil. It accounts for a minimum temperature with heavy rainfall throughout an average period of six months (April - August). The study area could be believed to contain sediments of varying lithology. There are two types of aquifers (Confined and Unconfined). But, present within the study area is unconfined aquifer. The study area was selected for investigation due to abortive and failed boreholes that were found in the region (kajola community) which has led to huge loss of time, resources and energy as a result of wrong citing of these boreholes, this problem now informed the employment of Vertical Electrical Sounding (VES) method and 2-Dimensional method for a better, accessible and reliable ways to identify for more potential, portable and quality source of water.

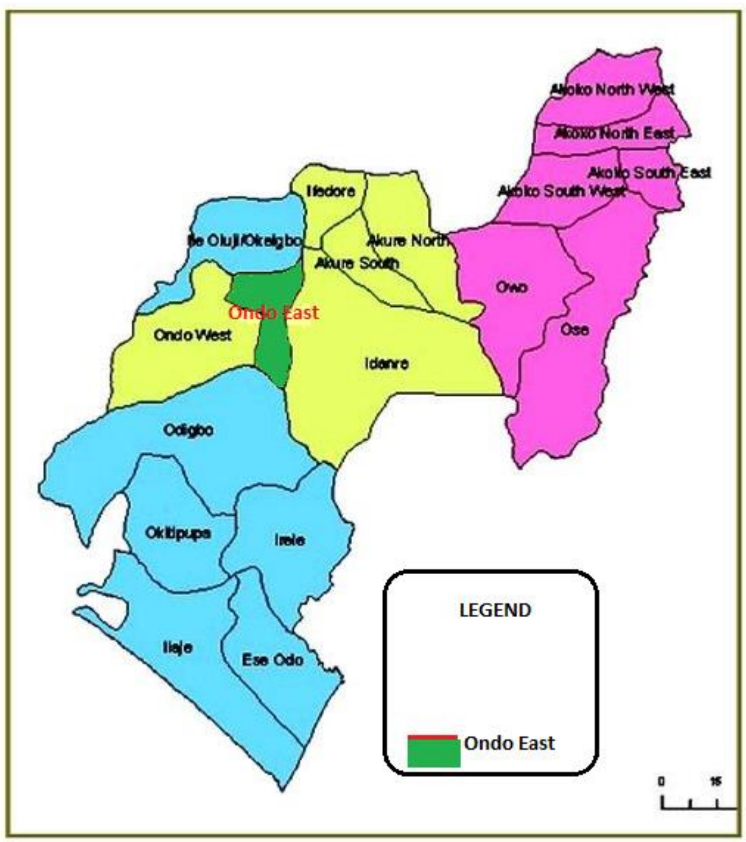

Figure 1 Ondo State map showing study area (Google Map).

2. METHODOLOGY AND DATA ACQUISITION

Seven VES points were distributed and collected using Schlumberger array configuration in the study area. The 2-D imaging survey was carried out using Wenner array configuration, because it is moderately sensitive to both horizontal and vertical geological structures. The combination is very helpful in acquiring lithology and groundwater exploration in study survey area. Ten (10) 2-D stations were carried out in the study area. Equal electrode spacing of 10m was used in the data collection.

3. RESULTS AND DISCUSSION

Results and Discussion of VES Data

The VES data acquired from the region were processed by adopting the partial curve matching technique. And this partial curve matching, involved the use of a standard layer master curves and four (4) auxiliary type curves, that is; H, K, A and Q. This is seen as basic interpretation of the field curves, which formed the parameters needed (Vander-Velper, 1988). The data and parameters obtained were inputted into the computer for iteration using the WINRESIST 1.0 software (Moscow, 2001). The parameters were subsequently varied until a best fit between the field and theoretical curves were got for each VES station. The parameters of the ultimate models brought the layer resistivity and thickness for the VES point, the geologic investigation that was carried out in Kajola community shows the qualitative interpretation from the data on table 1 showing VES 1 to VES 7 locations indicating a four-layer earth. The lithology of these locations from top to bottom is of top soil, sand, fine sand and clay. The average depth to aquifer is found in third layer which is the fine sand at the depth range between 13m and 20m.

Table 1 Summary of iteration result and lithology of the kajola town.

S/N	Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Curve Type	Probable Lithology
VES1	I	247.0	0.7	0.7	P1 < p2 > p3 > p4 KQ	Top soil
	II	2383.1	3.1	3.8		Sand
	III	204.1	5.1	8.9		Fine sand
	IV	177.7	_ _	_ _		Clay
VES 2	I	550.3	1.2	1.2	P1 < p2 > p3 > p4 Q	Top soil
	II	1158.8	4.0	5.2		Sand
	III	388.7	7.3	12.5		Fine sand
	IV	167.3	_ _	_ _		Clay
VES 3	I	1060.0	1.2	1.2	P1 < p2 > p3 <p4 QH	Top soil
	II	1434.2	6.5	7.7		Sand
	III	239.6	8.8	16.5		Fine Sand
	IV	492.8	_ _	_ _		Clay
VES 4	I	3183.9	1.6	1.6	P1 > p2 > p3 < p4 QQ	Top soil
	II	1746.8	5.1	6.7		Sand
	III	689.6	16.0	22.7		Fine Sand
	IV	817.7	_	_		Clay
VES 5	I	3070.7	1.6	1.6	P1 > p2 > p3 < p4 HA	Top soil
	II	2845.7	4.6	6.3		Sand
	III	346.8	10.2	16.5		Fine sand
	IV	3301.8	_	_		Clay
VES 6	I	1739.4	2.1	2.1	P1 > p2 > p3 < p4 QA	Top soil
	II	1005.5	5.7	7.8		Sand
	III	445.9	10.5	18.3		Fine sand
	IV	686.3	_	_		Clay
VES 7	I	3075.0	1.6	1.6	P1 > p2 > p3 < p4 KH	Top soil
	II	1815.9	6.4	8.0		Sand
	III	683.2	14.0	21.9		Fine sand
	IV	973.1	_	_		Clay

Results and Discussion of 2-D Imaging Data

The RES2DINV geophysics software Geotomo software, (2008), is used to interpret and create inverse images/models of measured data of the 2-D stations. The results of interpretation are given as follows:

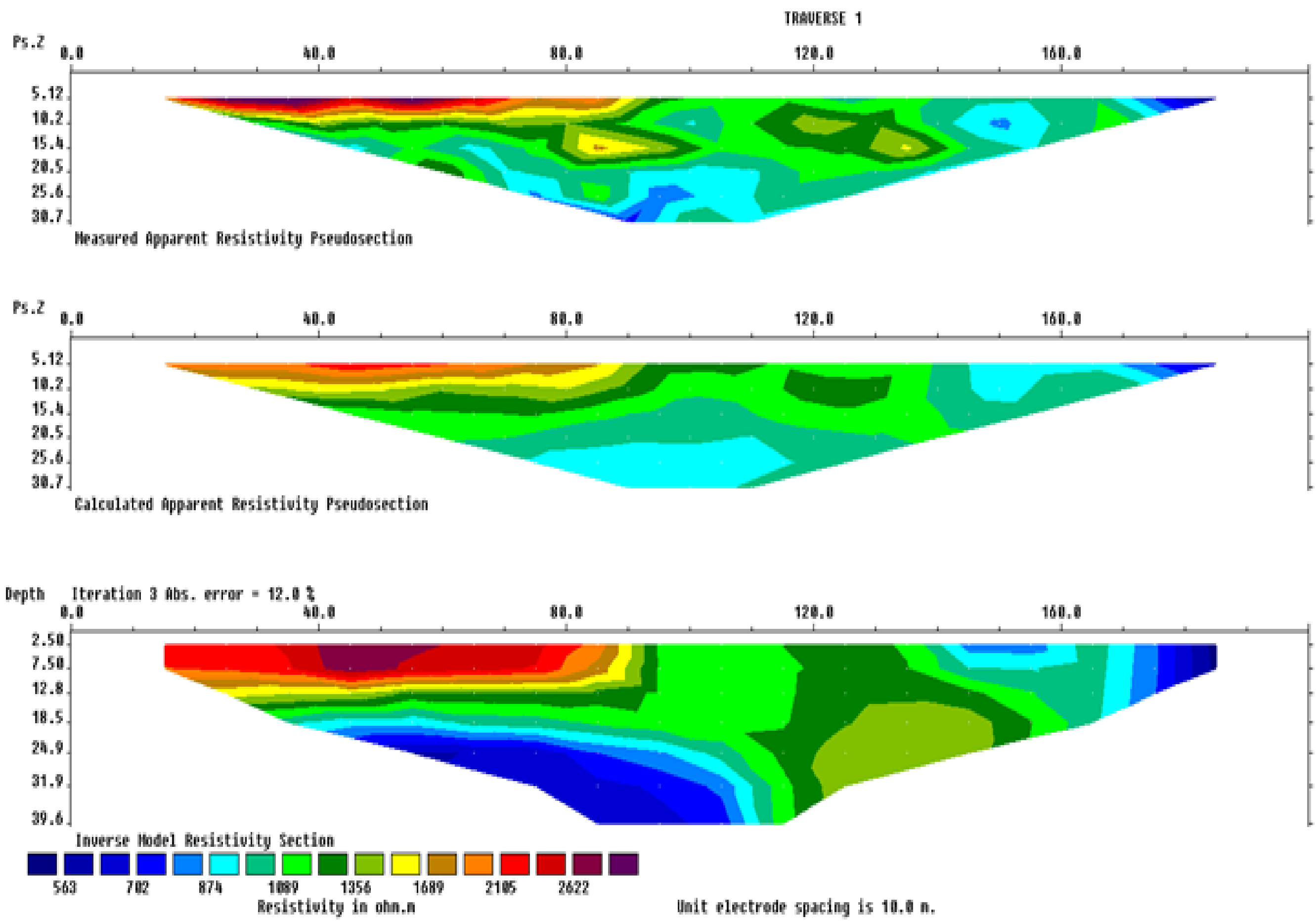

Figure 2 The 2-D electrical resistivity imaging along traverse 1.

2-D Resistivity Model for Traverse 1

Traverse 1 in figure 2 displayed 2-Dimensional inversion model with total depth of 39m which has the top layer to the depth of 12.8m to the subsurface and there is an indication of very high resistivity range between 1600 Ωm and 2800 Ωm in this layer at the lateral distance between 0m to 90m. However, in third and fourth layer there is low resistivity zone which fall between the ranges of 500 Ωm to 650 Ωm at the depth 18.5m to the subsurface and at the lateral distance between 40m to 110m. Therefore, this region is suspected to be aquifer zone.

2-D Resistivity Model for Traverse 2 and 3

Figures 3 and 4 displayed 2-Dimensional inversion model of traverse 2 and 3 of the study area. The top layer of the two traverses indicates very high resistivity range between 1300 Ωm and 2800 Ωm. However, low resistivity zones (between 400 Ωm and 650 Ωm) are indicated at the depth 24.9m to the subsurface and at the lateral distance between 50 to 110m. Therefore, this low resistivity region is suspected to be aquifer zone.

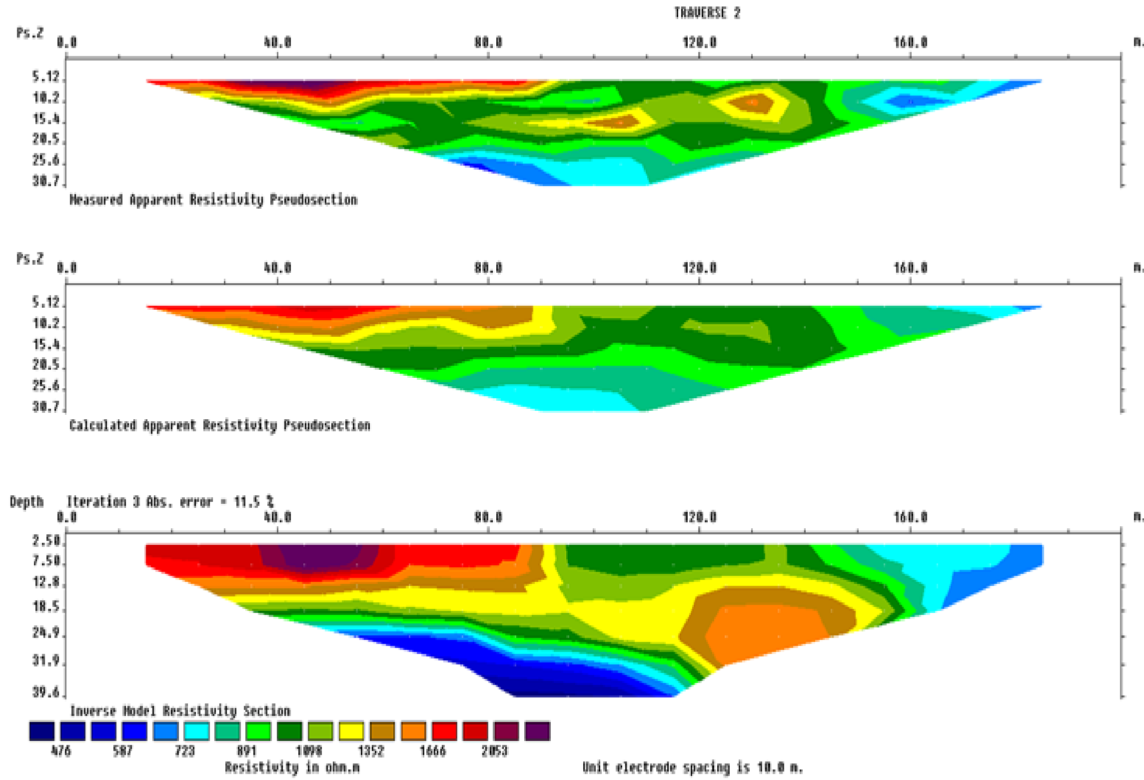

Figure 3 The 2-D electrical resistivity imaging along traverse 2.

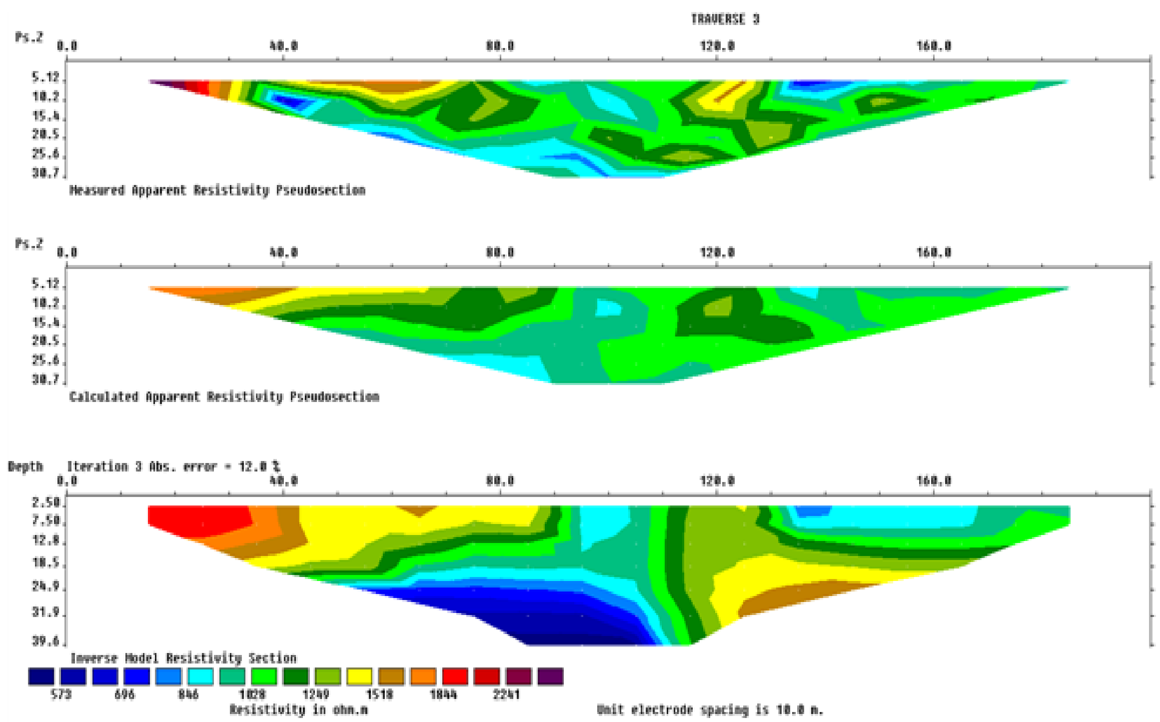

Figure 4 The 2-D electrical resistivity imaging along traverse 3.

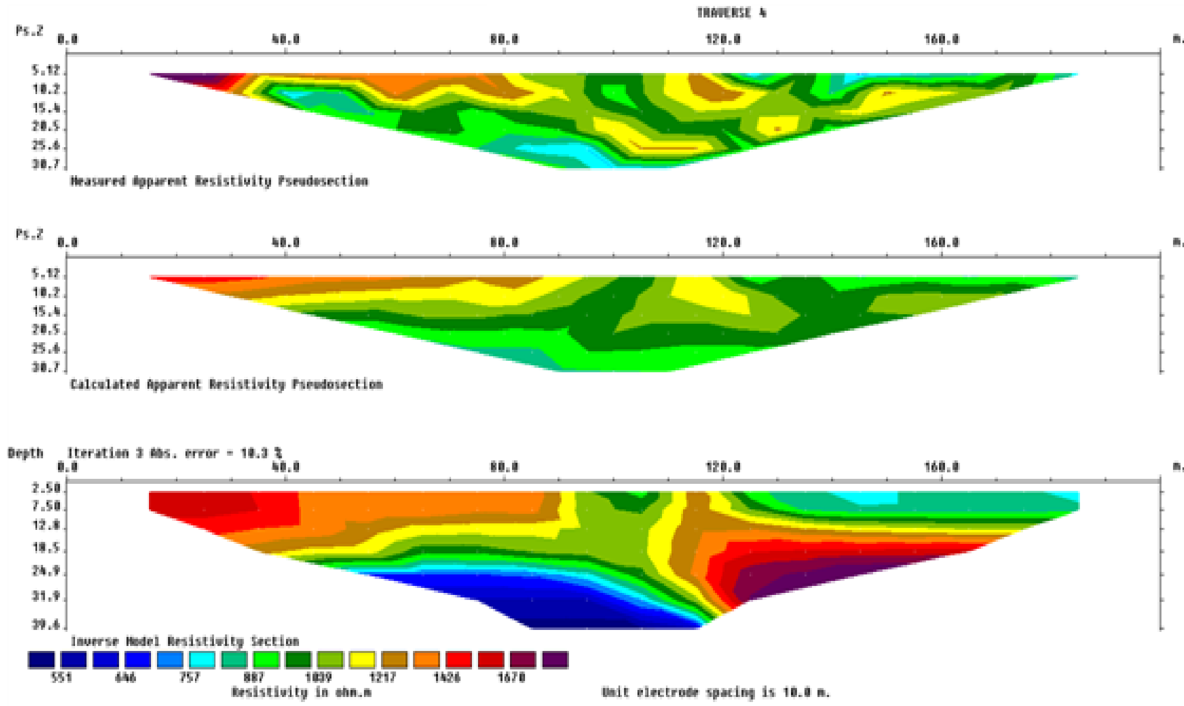

Figure 5 The 2-D Electrical Resistivity Imaging along Traverse 4.

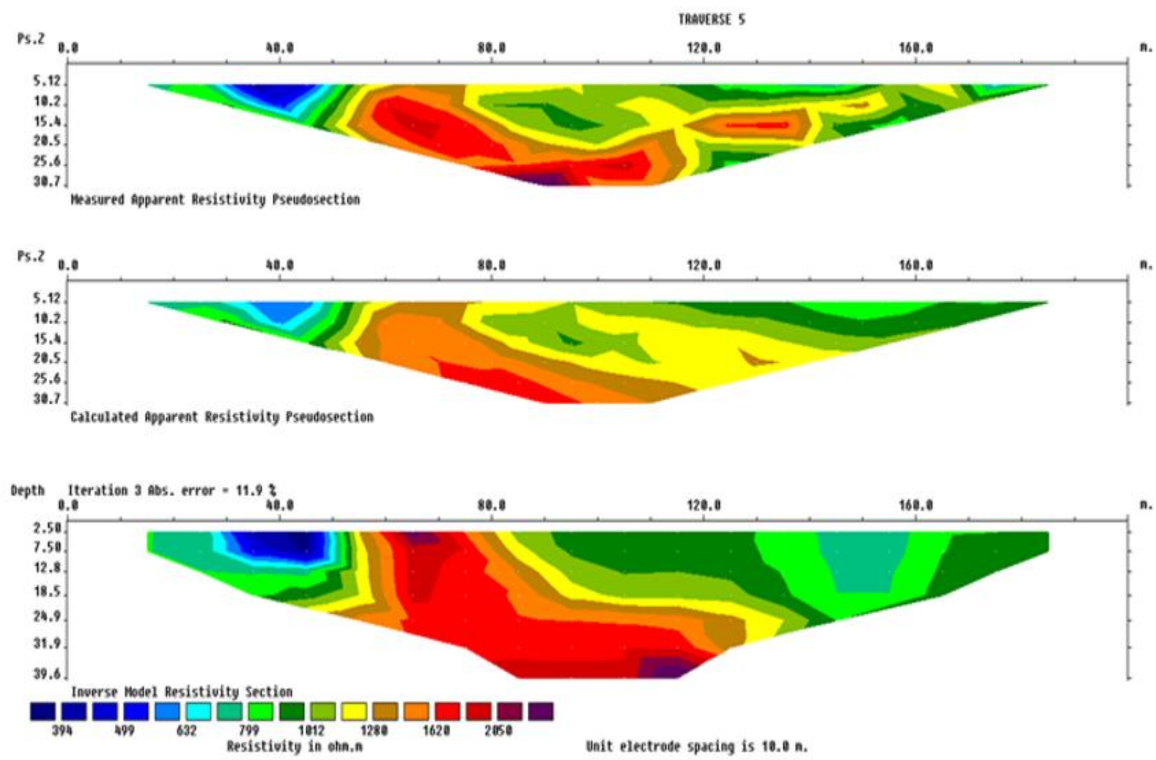

Figure 6 The 2-D electrical resistivity imaging along traverse 5.

2-D Resistivity Model for Traverse 5 and 6

Traverse 5 in figure 6 displayed 2-Dimensional inversion model with total depth of 39.6m which has the top layer with high resistivity values to the depth of 24.9m to the subsurface. There is lower resistivity range of 500 Ωm to 600 Ωm which fall at the lateral distance between 50m to 120m at the depth of 24m to the subsurface. This aquifer zone is suspected to be at third and

fourth zone. Traverse 4 in figure 5 also displayed 2-Dimensional inversion model which has low resistivity region which fall between 300 Ωm to 500 Ωm at top layer between the lateral distance 30m and 50m.

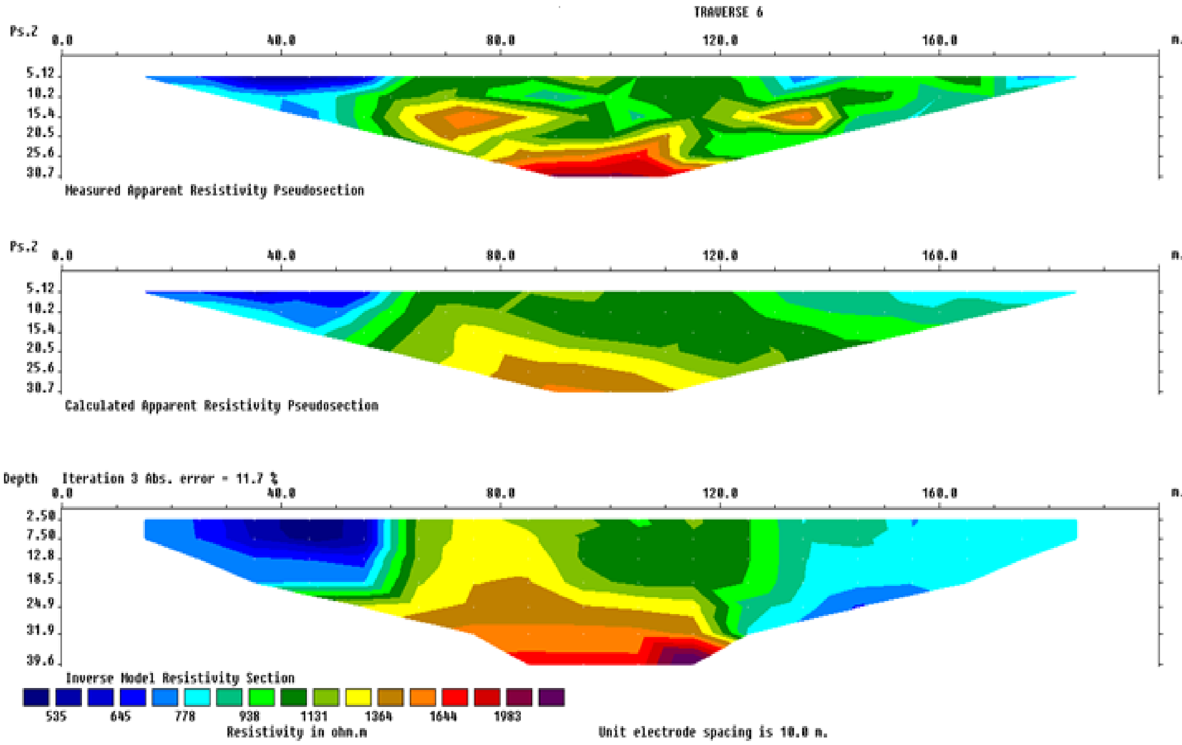

Figure 7 The 2-D electrical resistivity imaging along traverse 6.

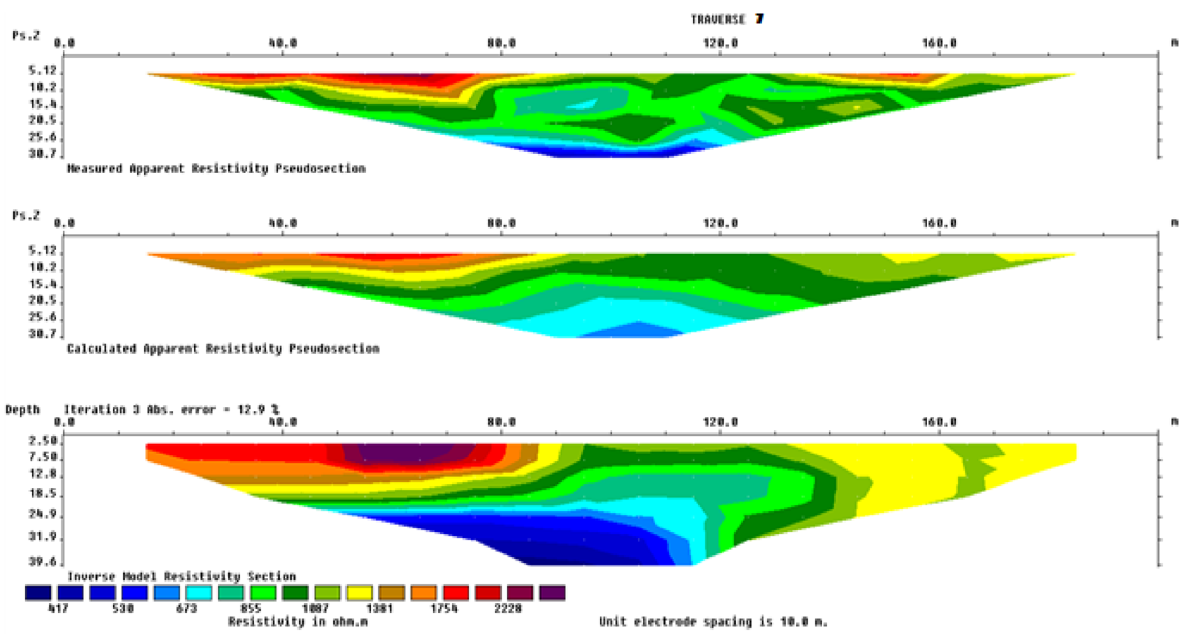

Figure 8 The 2-D electrical resistivity imaging along traverse 7.

2-D Resistivity Model for Traverse 6 and 7

Traverse 6 in figure 7 displayed 2-Dimensional inversion model with total depth of 39.6m which has low resistivity region which fall between 300 Ωm to 500 Ωm at top layer between the lateral distance 20m and 60m. Figure 8 displayed model of 2-Dimensional images of traverse 7 which has the top layer with high resistivity values to the depth of 24.9m. There is lower resistivity range of 400 Ωm to 500 Ωm which fall at the lateral distance between 50m to 120m at the depth of 24m to the subsurface. This aquifer zone is

suspected to be at third and fourth zone.

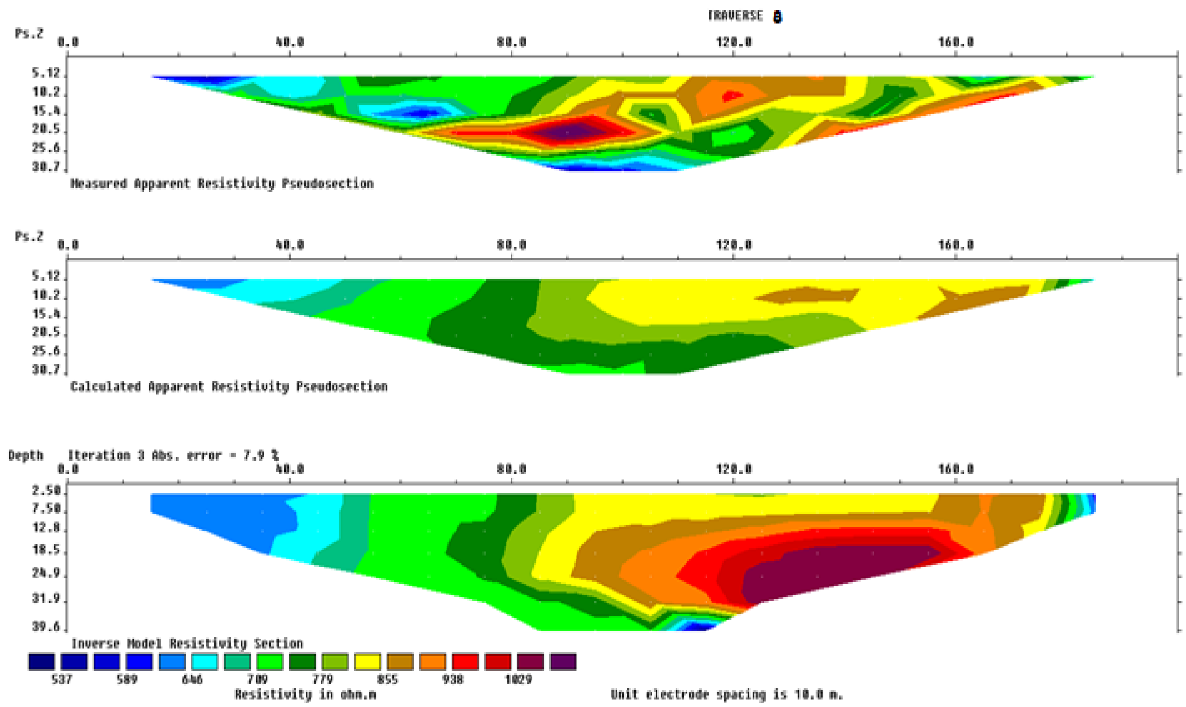

Figure 9 The 2-D electrical resistivity imaging along traverse 8.

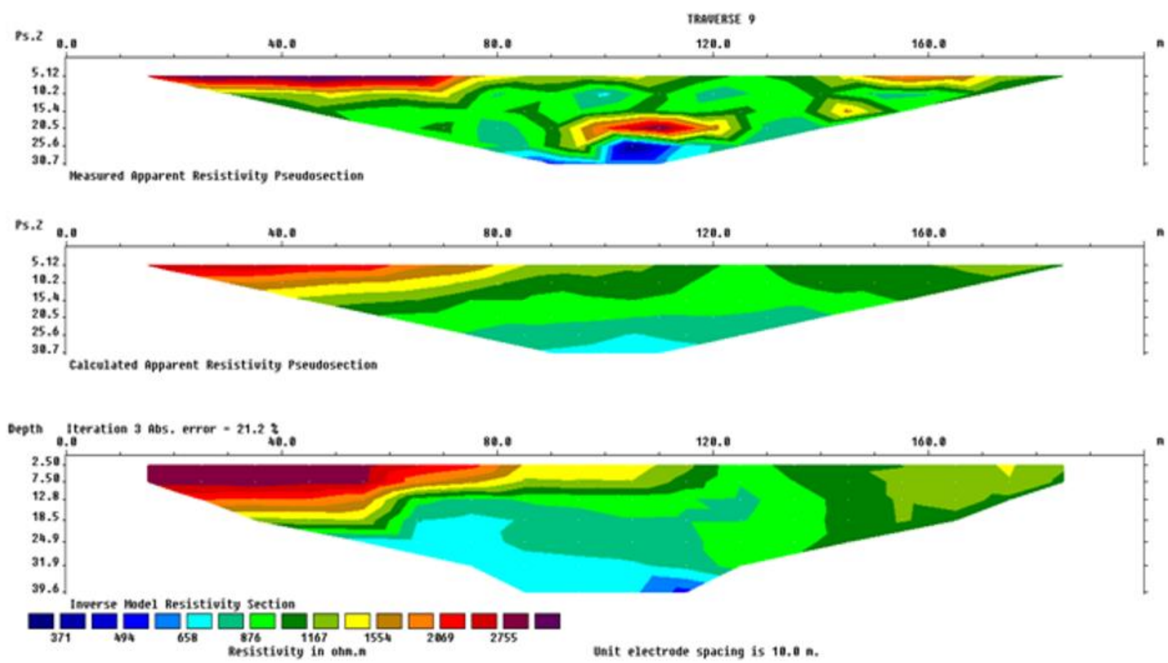

Figure 10 The 2-D electrical resistivity imaging along traverse 9.

2-D Resistivity Model for Traverse 8 and 9

Figure 9 displayed 2-Dimensional electrical resistivity imaging along traverse 8 in the study area. At the top layer of the traverse, there are indications of low resistivity at the traverse between 0m to 40m. This followed by higher resistivity regions to the subsurface. Also Figure 10 showed the model of 2-Dimensional electrical resistivity imaging along traverse 9 in the study area and the traverse is virtually filled with high resistivity region.

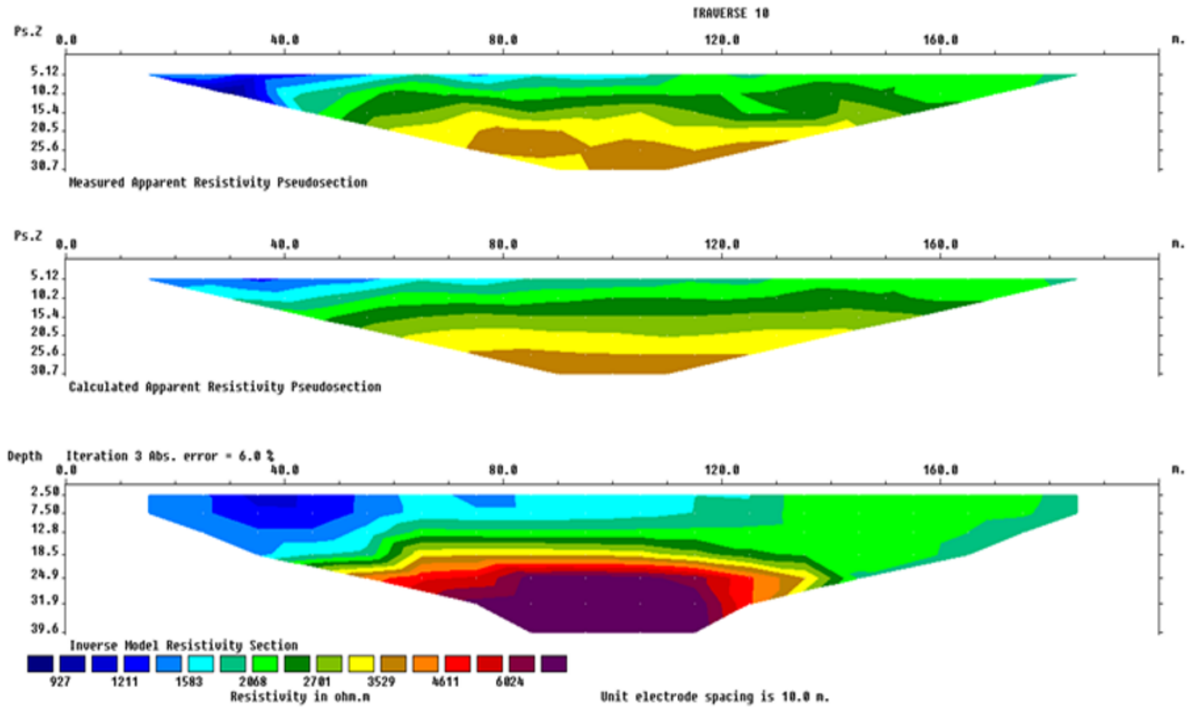

Figure 11 The 2-D electrical resistivity imaging along traverse 10.

2-D Resistivity Model for Traverse 10

Figures 11 displayed the models of 2-Dimensional electrical resistivity imaging along traverse 10 in the study area with total depth of investigation of 39.6m. The traverse displayed low resistivity region at top layer to the depth of 12.8m in the subsurface with a low resistivity value of 900 Ωm. This top layer followed by the depth range between 12.8m to 24.9m for second layer and 24.9m to 39.6m for third layer with high resistivity values between 1500 Ωm to 6024 Ωm.

Summary

The following were the findings from this research:

The Vertical Electrical Sounding method and 2-Dimensional method show that the area is underlain by four geo-electric layers namely top soil, sand, fine sand and clay and the aquifer is found in the third geo-electric layer which is fine sand.

Seven Vertical Electrical Sounding curves were acquired from the study area. It also revealed seven resistivity curve types namely; KQ, Q, QH, QQ, HA, QA and KH respectively while ten (10) 2-Dimensional resistivity distribution images/maps were got from the study showing low and high resistivity values.

Both the VES and 2-D maps were able to be used to determine the depth to ground water, aquifer thickness, and sub-surface lithology of the study area thus revealing its groundwater distribution.

4. CONCLUSION

The results obtained from the Vertical Electrical Sounding (VES) clearly indicate that the depth of the aquifer is 8.9m, 12.5m, 16.5m, 22.7m, 16.5m, 7.8m and 8.0m for VES 1, VES 2, VES 3, VES 4, VES 5, VES 6 and VES 7 locations respectively. In conclusion, the average depth to aquifer is found in third layer which is the fine sand at the depth range between 13m and 20m. The geologic layer of this aquifer zone is characterized by structural features like fractures and pore spaces that enhance groundwater permeability and storage. And the research has been able to determine the depth to ground water, aquifer thickness, and sub-surface lithology of the study area thus revealing its groundwater distribution.

Recommendation

It is recommended that more locations within the community should be investigated for more accurate sitting of boreholes using additional geophysical methods like seismic refraction method. However, this investigation has once again confirmed the fact that the combination of vertical electrical sounding and 2-Dimensional method is a reliable tool for underground water exploration.

Ethical approval

Not applicable.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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